Gold Coast Rapid Transit

3 System Requirements

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1 Mode and Vehicles

1.1 Preferred Modes

Previous studies have evaluated various modes for their potential to satisfy the requirements for a rapid transit system on the Gold Coast. Such modes have included expansion of bus services, monorail, bus rapid transit (BRT) and light rail transit (LRT).

The conclusion from previous studies are that BRT and LRT would meet the needs of the Project's Terms of Reference (ToR) for a transport system that was fast, frequent, cost effective, reliable and could meet initial and projected future demand. The Concept Designs that have been developed for BRT and LRT have determined that the alignments for both modes would be similar and would follow the same route.

Finally to satisfy the requirements for the GCRT system, the key criteria against which rapid transit vehicles were judged included the following:

- modern appearance;
- a high standard of passenger comfort and good accessibility;
- suitable size and an adequate degree of maneuverability to be able to operate within the GCRT corridor;
- ability to meet expected patronage demand;
- a high standard of safety;
- all or predominantly low floor;
- air conditioned;
- produce low emissions; and
- be economical in terms of capital and operating costs.

1.2 Bus Rapid Transit Vehicle Requirements

A number of BRT systems have been investigated for use on the GCRT Project including mechanically and electronically guided vehicles. BRT vehicles would be larger in size than the conventional buses currently in operation on the Gold Coast. Whilst it has been determined that guided systems would be unsuitable for the Project, a specific BRT vehicle has not been selected. However, recommended design parameters of passenger space allowance and general vehicle characteristics were established.

Generally, BRT vehicles would be modern and have an attractive appearance, have low floors, numerous doors and would be equipped with air conditioning. They would be powered by low emission engines such as compressed natural gas, diesel or hybrid diesel-electric. The BRT vehicles would be capable of reaching speeds of up to 70km per hour along the corridor.

The two types of BRT vehicles considered for the Concept Design were single-articulated and bi-articulated vehicles. Single-articulated vehicles are generally 18 metres in length overall and have one point of articulation. Bi-articulated vehicles are generally 25 metres in length overall and have two points of articulation. An example of a single-articulated BRT vehicle is shown in Figure 3 – 1.

Figure 3 – 1 Example of a Bus Rapid Transit Vehicle

1.3 Light Rail Transit Vehicle Requirements

There is a wide range of LRT vehicles in operation across Australia and around the world. At this stage a specific LRT vehicle has not been selected although recommended design parameters of passenger space allowance and general vehicle characteristics have been established.

Generally, LRT vehicles would be modern and have an attractive appearance, have low floors, numerous doors and would be equipped with air conditioning. The vehicles would be modular, which would allow for future extension of the capacity of the vehicles if required. The LRT system would be powered by 750 Volt direct current through overhead wires. LRT vehicles would be capable of reaching speeds of up to 70km per hour along the corridor.

Different lengths of vehicles have been considered, ranging from 27 to 45 metres, the latter being the longest known vehicle in operations. Based on patronage forecasts and the design life of the vehicles, various scenarios have been tested for the reference fleet over the proposed 30 year project life. The preferred strategy would be to operate with a fleet of 35 metre vehicles from the start of operation until 2041. 35 metre vehicles are generally made up of five modules, with three sets of bogies each with a chassis with four wheels. An example of a five module light rail vehicle is shown in Figure 3 – 2.

Figure 3 – 2 Example of a Light Rail Vehicle

1.4 Other Options

The Project Team received a considerable number of enquiries concerning the option of a monorail on an elevated overhead structure. This option was considered as part of the 2004 Gold Coast Light Rail Feasibility Study and was discounted due to high infrastructure costs, visual impact and access issues associated with elevated stations.

Elevated systems also lack the ability to integrate with the urban environment and are a solution often favoured by car drivers who do not want a public transport system to impact on road operations. Such systems have not been demonstrated to be cost effective solutions for mass transport needs and have demonstrated difficulties associated with access and interchanges. Research indicated that very few cities have implemented elevated solutions whereas dozens of cities around the world are implementing LRT and BRT systems.

Many members of the community have also frequently asked why the rapid transit system cannot be provided in a tunnel. In 2004, the Gold Coast Mayor commissioned a study to investigate the potential for road tunnels through Surfers Paradise. In addition to very high construction costs, the study revealed a need for significant property resumptions, potential for impacts on building foundations, likely impacts of exhaust points for tunnel ventilation upon existing high rise residential buildings, significant construction impacts and loss of road capacity for extended lengths of time.

Having regard to these matters and the significantly higher construction costs, the Project concluded that the substantial financial investment and significant disruptions during construction would not be warranted particularly since tunnelling would not reduce travel times or increase passenger numbers for the rapid transit system.

1.5 Comparative features of Bus Rapid and Light Rail Transit

Table 3 – 1 provides details which allow high level comparison between the key features of BRT and LRT vehicles and systems and is provided for information purposes.

Table 3 – 1 Comparison of Bus Rapid Transit and Light Rail Transit Vehicles and Systems

Features	Light Rail Transit	Bus Rapid Transit
Proven technology		
Which cities already use this technology?	LRT systems are found in many cities around the world. Cities with modern light rail systems include Paris, London, Dublin, Barcelona and Portland.	BRT systems are found in some cities around the world including Los Angeles, Las Vegas, Nantes and Ontario. However there are a limited number of BRT systems that operate within the existing road environment that have capacities above 50,000 passengers per day.
Ability to support future demand		
Vehicle size	Between 30 to 50 metres in length depending on the capacity required. The vehicles are modular, that is additional sections can be added as necessary. Internally the vehicles are between 2.5 to 2.65 metres wide with plenty of room to move around. There will be space for luggage storage and a minimum of two spaces for wheelchairs.	Up to 25 metres in length depending on the capacity required. The vehicles can be individual units, single or bi-articulated but the length can not be modified once the vehicle has been built. Internally the vehicles are between 2.4 to 2.55 metres wide with a centre aisle between seats. There is space for luggage storage and a minimum of two spaces for wheelchairs.
Passenger capacity	For this project the LRT vehicles must have a design capacity range of between 200 to 250 passengers. They must have at least 69 seats and be able to comfortably fit 129 standing passengers if necessary (based on 3 passengers per m^2)	For this project the BRT vehicles must have a design capacity range of between 96 to 117 passengers. The vehicle must have at least 34 seats and be able to comfortably fit 62 standing passengers if necessary (based on 3 passengers per m^2)

Ability to meet patronage projections	To support demand (core area) would require the following vehicles in peak periods: ◗ 2011 to 2016, 35m vehicle every seven to eight minutes ◗ 2016 to 2026, 35m vehicle every five minutes ◗ 2026 to 2041, 35m vehicle every three minutes	To support demand (core area) would require the following vehicles in peak periods: ◗ 2011 to 2026 - 18m single articulated vehicle every three minutes ◗ 2026 to 2041 - two single articulated vehicles running in tandem every three minutes ◗ 2041- two bi-articulated vehicles running in tandem.
Flexibility and ability to service major events	As light rail operates on a fixed track it is only able to operate within the dedicated rapid transit corridor. However extra vehicles could be used help disperse crowds quickly and easily following an event in the vicinity of the corridor.	One of the main benefits of BRT is the ability to run on normal roads for short periods of time if required. This means services could be redirected to support major events if necessary. However once the BRT vehicles leaves the dedicated rapid transit corridor the efficiency of the system becomes compromised by delays associated with the road network.
City Building		
Economic benefits	The economic benefits to the city from the GCRT Project were also assessed, see Volume 2, Chapter 11 Economic Environment. Consideration was given to whether there was any difference in the economic benefits generated by LRT or BRT systems. Experience from around the world suggested that LRT had more capacity to encourage development and contribute towards city building. However this was, in part, due to the fact that more LRT than BRT systems have been implemented in major cities and therefore more information was available.	
Value for money		
Whole of life costs	Whole of life comparative economic and costs analysis was undertaken as part of the mode evaluation. This included indicative capital, vehicle, operational and risk assessments of the BRT and LRT modes. Analysis was conducted on a long term basis, over 30 and 50 years of operation, to allow an appreciation of any differences over time. Capital costs analysed included items such as pavement and track, stations and land acquisition. Operational and vehicle costs included vehicle commissioning, staff costs, system establishment costs, routine maintenance of vehicles and infrastructure. Whilst it was found that the LRT was more expensive during the construction	

	phase (due mainly to additional cost of rail and electrification infrastructure), BRT was more expensive during the operations phase (due mainly to the need for more vehicles and associated costs). The analysis demonstrated that there was little difference economically between the two modes with the LRT being more expensive by approximately 10 percent. The economic cost assessment established that the net present value of all costs of the BRT option was $724 million and $812 million for LRT.	
Vehicle costs	These costs are indicative of the types of vehicles that would meet the requirements of the GCRT Project, in terms of capacity and level of service, and are dependent on a number of factors including: ◗ vehicles supplier; ◗ vehicle size and specification; ◗ fit out of interior; ◗ type and extent of information systems installed; and ◗ staging of Project (and therefore number of vehicles required).	
	LRT vehicles cost between $5.4 and $6.0 million per vehicle. Over a 30 year operating period the project would need to purchase 35 LRT vehicles.	BRT vehicles cost between $787,500 and $918,500 per vehicle. Although the cost per vehicle is much lower than LRT, significantly more BRT vehicles would be needed to meet the projected passenger demand. Over a 30 year operating period the project would need to purchase 97 BRT vehicles. A larger fleet of vehicles means increased costs for items such as personnel, maintenance and fuel.
Levels of service		
Journey times	35 minutes (Griffith University to Broadbeach, approx 12.4km long passing through 15 stations and 34 signalised intersections)	36 minutes (Griffith University to Broadbeach, approx 12.4km long passing through 15 stations and 34 signalised intersections)
Comfort	LRT vehicles operate on a fixed track providing a good ride quality, even when accelerating or decelerating and minimises passenger discomfort from unexpected sideways movement or sudden stops.	BRT vehicles are modern in design and offer a smother ride than existing buses but are still subject to driver judgment when docking, accelerating and decelerating.

Community preference		
Community and stakeholder preference	In 2005, GCCC formally resolved a preference for a LRT system and further confirmed this support again in 2007. This, along with the *2004 Light Rail Feasibility Study,* appeared to create a belief in the community that LRT was a foregone conclusion for the GCRT Project. Feedback on the choice of mode was not formally sought from the community. However, many people voluntarily gave us their opinion and preference. Preference for one mode or the other was one of the most consistent comments the project received. At the March 2007 the feedback we received indicated that: ◗ 67 percent of people preferred LRT; ◗ 23 percent of people preferred BRT; and ◗ 10 percent had a preference for different modes of transport.	
Other factors		
Power supply	For the Gold Coast Rapid Transit Project the LRT vehicles will be powered by electricity drawn from overhead contact lines with no local emissions. The power supply to the overhead wires will be 750 Volt direct current. Supporting poles are required every 40 metres and can be located in the median or to the side of the corridor. The power will be supplied through the Energex grid via electrical substations positioned along the route approximately every 1.5km to 3km. Ground supply of power, where cables are laid into the track, has not been considered for the GCRT Project due to reliability issues with technology that has not been commercially proven.	For the GCRT Project the BRT vehicles would be powered by the cleanest available energy source either hybrid diesel electric or compressed natural gas. The most reliable proven technology for articulated buses is Euro 5 standard diesel. Other options include diesel-electric hybrid vehicles and compressed natural gas although these are less reliable and have higher operating costs.
Emissions	The electricity to power LRT would currently be generated by coal burning power stations. However, in future, there may be the potential to generate electricity by the non-greenhouse gas generating methods including solar power, hydro power, geothermal power and wind power. Several of these types of electricity are already available in Queensland.	Emissions from BRT vehicles will not exceed the stringent levels set by the Queensland Environmental Protection Agency and the National Environmental Protection Council of Australia. However there will still be some emissions associated with either hybrid diesel electric or compressed natural gas.

	If the electricity is generated by the burning of gas or coal in a power station, there is the future possibility of geo-sequestration (capture and storage) of the CO_2 gas produced rather than releasing it into the atmosphere.	
Noise	The Queensland Environmental Protection Agency sets out criteria for acceptable noise levels. Average maximum acceptable noise levels on existing roads are currently set at between 60 to 63dB(a) depending on whether the road is State or locally controlled. The GCRT system generally follows existing road networks which already generate noise. Investigations have shown that neither mode would increase these noise levels to above accepted standards. As part of the draft Concept Design and Impact Management Plan the Project Team carried out noise monitoring at specific locations in order to confirm any potential noise impacts and developed suitable mitigation measures.	
Vehicle life	The operational life of LRT vehicles is expected to be around 30 years with refurbishment necessary about 12 to 15 years into service.	The operational life of BRT vehicles is expected to be around 15 years with no refurbishment necessary in this time. The vehicles will be inspected every 6 months with any necessary replacement parts replaced around 7 years into service. The BRT vehicles will undergo a detailed inspection after 20 years with the potential that their life could be extended to 25 years.
Vehicle suppliers	There are various LRT systems in operation around the world that would meet the requirements and level of service expected for the GCRT Project. These include: ◗ Bombardier; ◗ Siemens; ◗ Ansaldo STS; and. ◗ Alstom.	There are some BRT systems in operation around the world that would meet the requirements and level of service expected for the GCRT Project. These include: ◗ Volgren; ◗ Wright; ◗ Hess; and. ◗ Mercedes Benz.
Infrastructure	The proposed track form for the reference design is called encapsulated rail. The rails are encased within the track slab in such a way so the top of the rail is flush with the surrounding surface level. Different track forms were considered	Due to the high load and frequency a specific type of pavement is required for BRT vehicle. For this reason BRT vehicles cannot run on normal roads without causing deterioration to the road surface over a period of time. Different types of high performance

	and assessed again criteria such as constructability, maintenance and cost	pavement types have been assessed against criteria such as whole life cost, constructability and maintainability. Both concrete and deep asphalt pavement designs have been assessed with asphalt considered the most suitable.
Property impacts	Both modes require a similar corridor width in which to operate and therefore in the majority of areas the property impact would be the same regardless of mode. Refer to Volume 2, Chapter 10 *Social Environment* for more details.	
Traffic impacts	Detailed traffic modelling has been carried out by the Project. Refer to Volume 2, Chapter 8 *Traffic and Transport* for more details. The modelling found that the rapid transit system would not have a significant level of impact on the road network. However, as BRT vehicles have less passenger capacity than LRT, there is the potential, in future years, that BRT vehicles would have to be run in tandem (that is, one directly behind the other) in order to meet demand. The length of these vehicles, including allowing a safe distance between them, would mean that the vehicles took longer than LRT vehicles to travel through intersections. This could potentially affect waiting times at intersections.	
Construction time	Construction of the rapid transit system for LRT would take approximately 30 months. Refer to Volume 2, Chapter 6 *Construction Issues* for more details.	Construction of the rapid transit system for BRT would take approximately 27 months. Refer to Volume 2, Chapter 6 *Construction Issues* for more details

1.6 Mode evaluation

A detailed multivariable analysis of the BRT and LRT modes was undertaken to ascertain which mode would better suit the needs of the Gold Coast. The conclusion of the mode evaluation was that whilst the BRT system is cheaper in terms of costs (approx 10 percent cost difference) the LRT is justified on the basis that LRT has higher capacity and proven operational performance. LRT is considered best value for money for a high capacity mast transit system for the Gold Coast. Summary of the analysis is provided in Table 3 – 2.

Table 3 – 2 Mode Evaluation Summary

Summary	Comments
Whole of life financial and economic analysis	BRT has a cheaper capital cost profile however operationally the LRT is more efficient. On a whole of life basis the BRT system is approximately 10 percent cheaper. Economically the LRT system has higher benefits than the BRT system. On a cost benefit ratio both systems are considered to be viable. On a whole of life economic and financial analysis basis both systems have similar outcomes.
Capacity requirements and proven system capacity	LRT has a higher level of proven system capacity for the type of transport task required on the Gold Coast. There is a higher level of evidence that a LRT system will meet the capacity requirements on a long term basis when taking into consideration matters such as operational constraints and risks and peak loading demands. There are no current examples of BRT operating systems that can provide the system requirements for the Gold Coast within the corridor constraints of the GCRT.
Proven passenger level of service and other qualitative criteria	Both the BRT and the LRT meet the qualitative criteria required for the GCRT. Both systems support the continued development of the City however the LRT does have some added benefits in the areas of passenger level of service and community preference.

1.7 Whole of life financial and economic analysis

Comparative whole of life financial and economic analysis was undertaken for the two modes. It took into consideration 30 and 50 year operational cycles. Capital cost analysis took into consideration items such as:

- environmental management
- design
- urban design
- geotechnical investigation
- approvals and fees
- community consultation
- construction verification
- contaminated lands
- accommodation works
- advertising / public awareness campaign
- traffic management
- environmental management
- drainage installation
- earthworks
- pavements
- lighting
- traffic signals
- landscaping
- PUP relocations
- structures (bridges, retaining walls)
- stations
- rail infrastructure
- track work
- overhead wiring
- monorail relocation
- ITS
- depot and equipment
- power substations
- contractors facilities
- overheads
- commissioning
- demolition

Operational, vehicle and commissioning analysis took into consideration items such as:

- staff recruitment
- vehicle operator training
- insurance
- enterprise establishment costs
- registration and licensing
- rates
- routine maintenance
- vehicle acquisition
- fuel / electricity
- heavy maintenance
- ITS upgrades and replacement
- ticketing machines
- staff costs
- income tax
- payroll tax
- annual accreditation and compliance
- commissioning

Risk analysis took into consideration items such as:

- planned, unplanned and systematic risks
- process risks
- Monte Carlo analysis
- site
- design
- construction
- commissioning
- operations
- maintenance
- legal and legislative
- financial
- patronage and revenue
- industrial relations
- force majeure
- insurance
- vehicles
- escalation
- interest rates
- exchange rates
- timing and delays

Economic benefits took into consideration items such as:

- perceived benefits to car users;
- perceived benefits to public transport users;
- reduced unperceived car operating costs;
- reduced car ownership and parking costs;
- reduced commercial vehicle travel costs;
- increase in public transport fare revenue;
- reduced environmental costs;
- reduced accident costs; and
- land use benefits

Other issues such as advertising revenue, escalation rates, financial and economic cost of time rates (discount rates) were also taken into consideration. The analysis demonstrated that there was little difference financially and economically between the two modes. For more information on economic analysis refer to Volume 2, Chapter 11 *Economic Environment.*

The costs considered in the financial and economic analysis were used for comparative purposes and will not necessarily reflect the final project costs.

1.8 Capacity Requirements and proven system capacity

The GCRT system has significant passenger movement or system capacity requirements. Transport modelling shows that predicted peak passenger loading per hour for the system is provided in Table 3 – 3.

Table 3 – 3 Predicted peak passenger loadings

Year	2011	2016	2026	2041
Number of passengers (one way)	1,250	2,350	3,500	5,300
Number of passengers (bi directional)	2,500	4,700	7,000	10,600

An operational system capacity analysis was undertaken to assess various operating systems capabilities to meet the above capacity requirements.

1.8.1 System Operational Capacity

Operational system capacity analysis took into consideration:

- the Theoretical Ultimate Capacity of each mode;
- risks to it being achieved;
- the consequences of those risks; and
- an assessment of practical Operation Capacity for each mode

Each of these topics is discussed below.

1.8.2 Theoretical Ultimate Capacity

Theoretical Ultimate Capacity is a function of the number of vehicles that can be moved within a corridor per hour and the carrying capacity of those vehicles or:

Theoretical Ultimate Capacity = Number of Vehicles per Hour x Vehicle Carrying Capacity.

Vehicle carrying capacity is a function of the size of the vehicle, how the space within the vehicle is allocated (i.e. how many people seated, standing space, driver areas, doors etc.) and how many people who are standing can fit into a square area.

As part of the Concept Design, existing vehicle specifications and carrying capacity statistics were evaluated. These were then checked against systems operating in Australia, US and Europe, as well as, against a number of Australian and foreign transport policy positions for standing densities. The vehicle carrying capacities provided in Table 3 – 4 were adopted for normal operations and Table 3 – 5 was adopted for maximum loading or operations for short periods of time.

Table 3 – 4 Vehicle Capacity for Normal Operations

Vehicle Type	Seats	Standees (3 per m^2)	Vehicle Capacity
Articulated BRT	34	62	96
Bi-articulated BRT	48	89	137
35m LRT	69	129	198
45m LRT	91	169	260

Table 3 – 5 Vehicle Carrying for Maximum Loading or Operations for Short Periods

Vehicle Type	Seats	Standees (4 per m^2)	Vehicle Capacity
Articulated BRT	34	91	125
Bi-articulated BRT	48	127	175
35m LRT	69	180	249
45m LRT	91	233	324

The number of vehicle movements per hour was calculated by reviewing transport modelling data and assessing the maximum headways[1] that could be achieved in the corridor without adversely affecting general traffic movements to unacceptable levels. This was assessed as 3 minutes. Table 3 – 6 provides the resultant system ultimate capacities.

Table 3 – 6 Ultimate Vehicle Capacities

Vehicle Type	Vehicle Capacity	Vehicles per Hour[2]	Theoretical Ultimate Capacity
Articulated BRT	96	40	3,840
Bi-articulated BRT	137	40	5,480
35m LRT	198	40	7,920
45m LRT	260	40	10,400

For the BRT system, it was recognised that in order to meet the passenger carrying requirements of the GCRT new strategies to increase the Theoretical Ultimate Capacity were required. The following strategies were investigated:

[1] Headways are the time between vehicle movements

[2] Represents 3 minute headways, i.e. 20 vehicles per hour, travelling in each direction

- ***Grade separation and complete segregation of the BRT facility in the same manner as the South East Busway:*** High levels of capacity can then be achieved and if there are some traffic lights that need to be managed, tandem operation (or having one bus virtually immediately behind another) is acceptable. In this system, the number of berths and layout of stations dictate capacity of the BRT system. This type of system was considered to be unacceptable due to its high capital costs and high property, and other impacts.
- ***Overtaking facilities at all stations combined with express running services and all stop services:*** In this case, the stations would need to be belled out to allow for passing or a third lane built that vehicles could use under tidal flow arrangements (by driver sight to overtake). This type of system was considered to be unacceptable due to its high capital costs and high property and other impacts.
- ***Full priority system impacting more heavily on the traffic system by providing full priority for the rapid transit system at the expense of the overall network***: This type of system was considered to be unacceptable due to its high impacts on the transport network.
- ***Executing a different operational platform where the rapid transit services are supplemented by normal bus operations in the corridor to reach the required ultimate capacity:*** This required a significantly greater number of rigid buses to support the rapid transit system. Transport modelling and other analysis revealed that there were significant difficulties in executing this strategy including relatively low levels of patronage on the normal buses (due to poor service quality), high operational costs (due to the large numbers of drivers and extra vehicles required) and a large numbers of buses in the corridor which could otherwise be redeployed to other areas. Operational risks were such that it was also considered that the system would be unlikely to meet the ultimate capacity requirements. This type of system was considered to be unacceptable due to low service outcomes and high operational costs.
- ***Doubling the BRT vehicles through tandem operations (i.e. two all stop bus services together):*** There are difficulties in employing tandem operations in a highly urbanised and constrained environment. It was recognised however that there are difficulties in employing tandem operations in a highly urbanised and constrained environment.

Theoretical Ultimate Capacity Risks

Theoretical Ultimate Capacity provides a theoretical maximum capacity. In reality operational conditions and risks can erode Theoretical Ultimate Capacity by degrading either the:

- vehicle carrying capacity; and/or,
- number of vehicles per hour that can operate in the corridor.

Of these two, the vehicle carrying capacity is generally the easier to manage and to predict actual operational outcomes as it is the more controllable operating environment and the differences between the two vehicles are relatively minor[3] compared to the risks associated with the number of vehicles per hour that can operate in the corridor.

[3] For example, wider aisles in LRTs generally allow LRT vehicles to be loaded closer to their vehicle capacity than BRT vehicles. Higher ride quality also allows passengers to move around within the vehicle more readily meaning that passengers are more likely to move to the back of the vehicle or away from the doors allowing for standee space to be more readily used. Vehicle

There are a number of risks that can affect the capability of a transport system to operate efficiently in a chosen corridor including:

- variation in dwell times at stations occurring due to:
  - variation in time taken to approach a station;
  - variation in docking speeds;
  - if specified platform gaps are not achieved, time to deploy ramps;
  - ingress and egress of patrons to and from vehicles; and
  - time to leave a station;
- variation in average travel speeds, cornering speeds, acceleration and deceleration characteristics;
- variation in approaches to traffic lights, traffic light priority systems and time taken to travel through intersections;
- number of vehicle break downs, maintenance requirements (eg. tyre replacement) and other incidents;
- having to wait for another vehicle at a station or in the corridor;
- normal variation in run times due to not having full priority at signals (eg. one vehicle catches a red light at the start of a signal and another catches all the green lights); and
- variations in driver performance.

BRT and LRT systems have different levels of capability to manage these risks. Whilst there are a number of options which are available to both systems[4], generally, the LRT can better manage these risks. For example, LRT features include:

- being on rails which reduces variations in docking distances and alleviates the need for ramps;
- wider aisle and door areas reduces variation in patron ingress and egress in and from vehicles;
- high reliability and more accurate traffic signal priority systems; and
- variations in average travel speeds, cornering speeds, acceleration, deceleration and driver performance are reasonably limited (vehicle is on rails and various operating systems assist the driver to manage the vehicle).

Whilst the BRT system does have some access to these options generally they are not as highly developed as for LRT. BRT tends to rely more on driver training to manage these risks.

Generally these risks create a level of variation in travel times (i.e. lack of reliability). When operating at very high frequencies (3 minute headways is considered to be a very high frequency), these variations in travel times result in bunching and/or an inability to maintain the headways[5].

congestion loading is experienced sooner in smaller vehicles meaning that BRTs will suffer loss of effective ultimate capacity before LRTs.

[4] Such as, passenger information systems which can assist managing passenger ingress and egress to and from vehicles, personal address systems at stations and on vehicles etc.

[5] There are various management techniques to manage bunching which include use of radio communications and driver training, however, ultimately without the application of additional resources and costs, eventually there is a loss in headways.

As such, a LRT is more reliable for a mass, line haul system than a BRT (i.e. where high frequency headways are required in a system which does not have both total segregation and overtaking capability to assist in maintaining reliability risks).

With the introduction of tandem operations, not only are the risks doubled but also the following additional risks are accrued:

- Variation in minimum safe distance requirements between vehicles cause delays in the time taken to approach or leave a station and time taken to traverse traffic lights;
- Uneven capacity loading of vehicles either directly reduces vehicle capacity or, alternatively, increases dwell times at stations as patrons ascertain that the first vehicle is full and as such, the two vehicles wait until the passengers move to the second vehicle;
- Uneven ingress and egress loading time achieved by either vehicle resulting in station dwell times increasing; and
- Variations caused by the uneven operation of the two vehicles meaning that the two vehicles will operate at the effective speed of the slower vehicle due to differences in driver performance and other factors.

Whilst both BRT and LRT systems have high Theoretical Ultimate Capacities, the BRT has fewer mitigation strategies available to assist in managing system capacity risks. Using BRTs in tandem operation (which is the only system which could achieve capacity requirements) more than doubles the risks as there are twice as many vehicles and additional risks are accrued.

This is evidenced in that there are numerous operational LRT systems that undertake a similar transport task to the GCRT, however, there are no current operational BRT systems of a comparable nature.

1.8.3 Risk Consequences

There are three main consequences of these risks:

- Loss of patron satisfaction and/or loss of attractiveness of the rapid transit system due to high variations in travel times and generally higher than originally estimated travel times;
- Increased capital or operational costs in order to maintain headways; and/or,
- Increased headways which reduce Theoretical Ultimate Capacity.

Loss of Patron Satisfaction

High levels of variations in travel time or generally increased travel times result in loss of patron satisfaction and the attractiveness of the rapid transit system. Table 3 - 7 shows the non-mode specific impacts of variation in travel times in terms of lost patronage predicted by the Transport Model.

Table 3 – 7 Non-mode specific impacts of variation for lost patronage

Travel time lost per station	Base	+15 seconds	+20 seconds	+30 seconds
% of patronage of base	100%	95%	92%	90%

The consequence of this is a general loss of service requirements resulting in a loss of patronage on the rapid transit, the public transport system in general, increased car usage and loss of fare box revenue.

Increased Capital or Operational Costs

Increased capital or operational costs include:

- increased number of vehicles and vehicle operators in order to ensure headways can be met;
- additional staff and systems at stations to assist patrons to board or alight vehicles; and
- and grade separating intersections or introducing overtaking lanes.

These solutions have high cost and impacts and are considered to be not viable or affordable.

Increased Headways

If the increased capital and operational costs solutions are either not viable or are ineffective, the net result is a loss in headways which reduces Theoretical Ultimate Capacity of the BRT or LRT system to their practical Operational Capacity. An analysis of this loss was undertaken to understand the impact on Theoretical Ultimate Capacity and to ascertain the practical Operational Capacity that may be achieved during operations.

The LRT system is well developed and understood, and has proven risk mitigation strategies. There are numerous examples of similar LRT systems undertaking transport tasks as required for the GCRT. As such, there is a high degree of certainty that the Theoretical Ultimate Capacity will be reached or nearly reached.

The single vehicle and tandem vehicle BRT systems are less well understood and have fewer mitigation strategies available. There are no current examples of single vehicle or tandem vehicle BRT systems operating within a dedicated at grade rapid transit system that can meet the capacity requirements for the Gold Coast. As such, there is a higher likelihood that the Theoretical Ultimate Capacity will be eroded during operations.

Table 3 – 8 shows the normal Operational Capacity that could be achieved on an hourly basis. For short periods of time each system can reach slightly higher levels as standing room densities increase from 3 persons per m^2 to 4 persons per m^2 (although operational efficiency can degrade during these periods).

The GCRT has a projected peak period requirement of 10,600 persons per hour. Of the systems reviewed above only the 45m LRT will have a comfortable level normal Operational Capacity and a comfortable level of short-term capacity. Given the modular nature of the LRT this will allow a 35m LRT to be upgraded to a 45m LRT as demand grows and the system will be able to meet the operational capacity requirements of the GCRT.

Table 3 – 8 Practical operational capacity for each of the options

Operating Systems	Operational Capacity	Short-Term Capacity
Single Vehicle Articulated BRT	3,200	4,100
Single Vehicle Bi-articulated BRT	4,600	5,800
Tandem Operation Articulated BRT	5,100	6,600
Tandem Operation Bi-articulated BRT	7,300	9,300
35m LRT	7,200	9,000
45m LRT	9,500	11,800

1.8.4 Passenger level of service and other qualitative criteria

A number of passenger level of service and other qualitative criteria were taken into consideration such as:

Ride quality and comfort

System requirements for acceleration and braking are similar for both systems. By its very nature, a fixed track system will provide better ride comfort in terms of vehicle sway (passenger sideways movement) and surface roughness (passenger vertical movement). While there are no defined standards for either, and no means of quantifying the difference, it is widely acknowledged in the transport industry that LRT offers significant advantages with passenger comfort that could ultimately be converted into patronage benefits.

Accessibility

Theoretically, both systems can achieve the same level of accessibility and allow roll on / roll off access at platforms. This relies on minimised gaps (vertical and horizontal) at station platforms. By its very nature, a fixed track system will achieve excellent docking performance consistently. For BRT systems, docking relies either on driver performance or mechanical ramps, or a combination of both, with a risk of uneven performance and mechanical failure if not properly maintained.

Positive impact on Gold Coast image, attractiveness and community preference

Both systems would have a very positive impact on the Gold Coast Image, conveying themes such as sustainability, accessibility, mobility and modernity. However, LRT being a completely new system of transport, its appeal to the resident population and tourist population could prove superior to a bus based system.

Community consultation activities undertaken in March and October 2007 generated unsolicited feedback regarding preference for mode and indicated greater support for light rail.

Visual amenity

The principal issue is overhead wiring associated with LRT systems. In Australia, where street environments are often dominated by existing street lighting and overhead electricity and communication cables, additional wires are unlikely to cause additional impacts. However, the proposed GCRT corridor travels along sections of Southport CBD and Surfers Paradise characterised by an absence of overhead systems. Therefore, despite modern LRT systems developing more elegant catenary systems and integrated with street lighting, a visual impact will be created.

Safety of operations

Accident statistics for most cities demonstrate that LRT and BRT systems are inherently safe. It is therefore concluded that both systems can be designed and managed to be safe and that neither mode offers significant advantages in that respect.

2 Rapid Transit Infrastructure

2.1 Bus Rapid Transit Infrastructure

2.1.1 Pavement

Due to the high load and frequency of BRT vehicles, the design and implementation of a specific type of pavement is required. Different types of high performance pavement types have been assessed against criteria such as whole of life cost, constructability and maintainability. It was concluded that a BRT system would require a full depth asphalt pavement of a wearing course, binder layer and base layer with a total depth varying between 370 millimetres (ten percent CBR) and 420 millimetres (three percent CBR). In the vicinity of all stations and layover areas, continuously reinforced concrete pavement with a total depth of 330 millimetres (sub-grade conditions ranging from three percent CBR to ten percent CBR). CBR refers to California Bearing Ratio which is a penetration test for evaluation of the mechanical strength of road subgrades and basecourses.

2.1.2 Turn-around and Layover Facilities

At each end of the line, turn-around facilities and layover facilities have to be accommodated. The land requirements for a turn-around facility for BRT vehicles are significant and would limit the number of options for end of line layouts.

2.2 Light Rail Transit Infrastructure

2.2.1 Light Rail Track Form

Different track forms have been considered and assessed against criteria such as constructability (ease and duration of construction, ability to divert general traffic on running way), maintenance (in particular ease of replacement of track), cost, ability for shared running scenarios (emergency services access), vibration attenuation and urban design. The proposed track form for the Concept Design is what is called encapsulated rail whereby the rails are encased within the track slab in such a way so the top of the rail is flush with the surrounding surface level. The method for encapsulating the rail involves casting a steel reinforced concrete slab with continuous longitudinal grooves. The rails are positioned in the grooves and fixed in place by surrounding them with an elastomeric or resilient rubber compound.

2.2.2 Light Rail Power Supply

Light rail vehicles use a 750 Volt direct current supplied by an overhead contact wire (overhead catenary). Supporting poles are required every 40 metres and can be located either in the median of the corridor between the two running ways or to one side of the corridor. There is also an opportunity to affix overhead wires to adjacent buildings and this will be considered during detailed design.

The system power will be supplied from the electrical grid, via electrical substations positioned along the route at approximately every 1.5km to 3km. There will be a level of redundant power supply sufficient to ensure that should a substation have a failure, the adjacent substations will allow continuity of power supply with little or no impact on rapid transit operations.

A major issue with a direct current traction power supply is the phenomenon of stray current, which can potentially affect the integrity of underground pipes and structures containing steel elements. The key protection measures which will be used to protect against stray current include:

- rail isolation which is achieved by surrounding them with a rubber material; and
- installation of a stray current collection system which is achieved by a series of grids of welded steel reinforced bars embedded in the track slab

2.2.3 Cross-overs

The management of light rail vehicle breakdowns or incidents requires cross-overs at regular intervals. This will allow vehicles to switch track and bypass the closed down section of adjacent track.

2.2.4 Turn-around and Layover Facilities

At each terminus, turn-around facilities and layover facilities have to be accommodated. The light rail vehicles will have cabins at the front and rear of the vehicle. The turn-around manoeuvre is done using a section of track with a cross-over.

2.3 Rapid Transit Stations

Station locations were determined by a number of factors including population centres, important trip generators (destinations), existing intersection locations and a preferred spacing between stops of approximately 800 metres.

2.3.1 Station Design

Stations have been designed where possible to take account of the key features of the existing or planned urban environment. The design of the stations has also taken account of “Crime Prevention through Environmental Design” (CPTED) principles to provide a safe and secure environment that is also welcoming, comfortable and accessible for all users. Station security features will include CCTV coverage, public address systems, and help points with interactive video and audio capability.

The design, layout and features of the stations have been developed to take account of the requirements for each location including peak passenger loadings, passenger storage requirements, interchange with other public transport services and modes and park and ride opportunities. The size of the platforms for stations reflects relevant vehicle lengths and is based on the Disability Discrimination Act (DDA) and the requirements set out in the Transit Capacity and Quality Services Manual (Transportation Research Board, USA, 2004) to achieve a level of service. These documents provide guidance on the desirable average pedestrian space, personal comfort, internal mobility and required circulation space along the platform.

For the Concept Design, three general station types have been developed, namely Regional, District, and Local. The design, layout and features of each of these station types are described below.

2.3.2 Regional Stations

Regional Stations will be located near major patronage attractors such as regional shopping centres and will provide the highest level of facilities and services of the station types. Regional stations will allow for interchange with other transport modes. Some of the key facilities that will generally be provided at a Regional Station (subject to on site sizing constraints) are listed below:

- Shelters
- Seating
- Kiss 'n' Ride facilities
- Public Toilets
- Ticket / Information Booth
- Ticket Machine
- Route Maps / Fare Information / Timetables
- ATM
- CCTV
- Real Time Passenger Information
- Help Points / Emergency Telephone
- Public Telephone
- Bicycle Storage

2.3.3 District Stations

District Stations will be a significant attractor for patronage on the network and will have a good standard of passenger facilities. Some of the key facilities that will generally be provided at a District Station (subject to on site sizing constraints) are listed below.

- Kiss 'n' Ride facilities
- Shelters
- Seating
- Ticket / Information Booth
- Route Maps / Fare Information / Timetables
- Ticket Machine
- CCTV
- Real Time Passenger Information
- Help Points / Emergency Telephone

2.3.4 Local Stations

Local Stations are designed primarily to cater for the transport needs of the immediate community. The primary means of access to a Local Station will be walking via local paths and roadways. Some of the key facilities that will generally be provided at a Local Station (subject to on site sizing constraints) are listed below.

- Shelters
- Ticket Machine
- Real Time Passenger Information
- Route Maps / Fare Information / Timetables
- Seating
- CCTV
- Help Points / Emergency Telephone

2.3.5 Passenger Information Systems

The rapid transit system will be equipped with a real time passenger information system. The provision of a real time information system allows patrons to make more informed choices and thereby have increased confidence in the system. It is proposed that information will be provided at stations and within the vehicles.

Passenger Information Display (PID) monitors will be located at each station platform displaying real time arrival and departure information for services.

Information displayed may include vehicle progress, information about connecting bus and/or rail services and local advertising. The rapid transit vehicle will also be fitted with an internal Public Address (PA) system. The PA system will be used to announce the next stop and connecting services, as well as driver and emergency announcements.

3 System Operations

3.1 Operational Priority

Operational priority is a key factor to the success of the GCRT system and will be achieved by:

- Providing physical priority for vehicles i.e. physical separation from potential conflict with other traffic; and
- Providing signal priority for rapid transit vehicles at locations (generally intersections) where physical separation is not provided.

These are outlined below:

Physical Priority

The majority of the core service route operates in a segregated corridor, i.e. an existing road corridor at grade with some form of separation from general traffic. This is generally achieved by having a raised kerb separating the rapid transit vehicles from general traffic.

There is only one section where physical separation will not occur and this will be along Cypress Avenue. This will require mixed operation where the operation of rapid transit vehicles will be at grade on an existing road corridor and where vehicles will mix with general traffic and pedestrians.

Signal Priority

Three scenarios for different levels of system wide priority for rapid transit vehicles at intersections were developed:

- Full priority where full, pre-emptive signal priority is provided at all intersections, so the rapid transit vehicle will experience no delays;
- High priority where signal priority is provided at most intersections unless the intersection is particularly complex or congested. Priority could be full, pre-emptive or partial; and
- Moderate priority where signal priority is provided for rapid transit vehicles at locations and at a level that will not unduly affect existing traffic operations.

The Concept Design has been based on achieving a high level of signal priority for rapid transit vehicles. This level of priority will allow the rapid transit system to function with a high level of reliability and will have a manageable impact on the road network. Further information on operations may be found in *Chapter 7, Operations*.

3.2 Pedestrian Movements

Along the GCRT route, the footpath will be reinstated according to GCCC guidelines (i.e. a minimum of 3.5 metres wide although 4.5 metres is desirable). Pedestrian crossings will be maintained at all signalised intersections and with low kerb interface with the pavement, a large waiting area on the footpath and tactile indicators. At grade signalised crossings will be provided at all rapid transit stations.

3.3 Cycling

The general principles adopted with respect to cycling provision are as follows:

- Where an itinerary has been identified in the planning documents (Integrated Regional Cycle Network Plan and GCCC Cycling Network plan), the implementation of the rapid transit corridor should not preclude the future implementation of these cycle routes;
- Where a cycle route exists along the rapid transit corridor, it will be reinstated as part of the GCRT Project.

In Section 2, there are existing facilities as follows:

- Queen Street (Wardoo Street to Mal Burke Street) on road shared;
- Queen Street (Mal Burke Street to Carey Lane) on road;
- Queen Street (Carey Lane to Nerang Street) on road shared;
- Nerang Street (Queen Street to Scarborough Street) on road;
- Scarborough Street (Nerang Street to Short Street) on road; and
- Scarborough Street (Short Street to Queen Street) on road shared;

These facilities will be largely reinstated (in the form of dedicated on road lanes) and extended along Queen Street from the Scarborough Street intersection to Ada Bell Way. The existing cycle facilities on the Nerang River Bridge will be improved with the construction of a new pedestrian and cycle bridge funded by GCCC.

In Section 3, the implementation of cycle lanes along the Gold Coast Highway between the Sundale Bridge and Ferny Avenue will not be precluded by the rapid transit corridor, which will be located on the western side of the Highway. Along Ferny Avenue, there are no existing facilities due to spatial constraints and no provision is made in the GCRT Project. Along Surfers Paradise Boulevard, cycles will be able to mix safely in the one way southbound travel lane in a low speed environment (30km per hour). South of Surfers Paradise Boulevard, built environment constraints are such that provision for cycle lanes cannot be made at Concept Design level. However, opportunities to accommodate them will be investigated at the detailed design stage when further refinement of the cross section will be undertaken.

3.4 Depot and Rapid Transit Operations Centre

The depot for the rapid transit system is to be located on the site of the current GCCC depot and accessed from Michelin Street in Southport. This site is located adjacent to the rapid transit route and is suitable for 24 hour access due to the surrounding land use (industrial mixed use with some open bush land). The size of the available land is approximately 52,000 square meters, which is sufficient to cater for the requirements of a functional depot. The key requirements of the depot are as follows:

- facilities for routine vehicle inspection, maintenance and minor repairs;
- spare parts store to be located adjacent to the maintenance building with adequate spare parts to carry out routine and minor vehicle maintenance;
- training facility for drivers and other staff;

- control centre building for signal control, radio communications with fleet, CCTV monitoring and general operations management;
- stabling yard to store vehicles after they have been inspected, repaired and washed;
- wash-on-return facility to wash down vehicles at the end of each day and to be located preferably between the fleet entrance and stabling or adjacent the fleet entrance to the depot;
- fuel storage and fuel dispensing facility for BRT vehicles*;
- sand filling machine for on board sand tank for light rail vehicles for spilling sand on track when increased friction is required between the wheel and the track;
- substation for light rail; and
- parking facilities for staff, visitors, general maintenance, utility and ancillary vehicles and oversize vehicles.

The Operations Centre will be located within the depot. The Control Centre shall be the central control point for the remote operation of the GCRT. The Operational Centre will be staffed 24 hours a day and seven days a week. Further information may be found in Volume 2, Chapter 7 *Operations*.

4 Design and Construction

4.1 Design and Construction Program and Key Impacts

It is anticipated that a BRT or LRT system may be constructed and commissioned within 34 to 36 months respectively from financial close (i.e. when all contractual matters of a financial nature have been resolved). The GCRT Project has a commitment to:

- promote the highest levels of safety in the vicinity of the construction sites, for road users (vehicles, cycles), pedestrians and adjacent properties (residential and commercial);
- minimise the impact on the traffic network as far as reasonably practical, whilst promoting efficient construction methods;
- listen to concerns and working with the community and stakeholders to manage impacts associated with construction;
- provide reasonable access to business and residential properties during construction;
- provide excellent communication in order for stakeholders and the community to have a clear understanding of construction activities and potential impacts; and
- minimise overall impacts to the Gold Coast City during construction.

The key issues and impacts associated with construction are as follows:

- construction work at night;
- parking provision;
- access to business and residential properties;
- impacts on traffic and diversions (macro and micro);
- impacts on existing bus services;
- environmental impacts;
- noise and vibration;
- the need to maintain work sites in a clean and tidy state;
- construction planning;
- logistics i.e. the movement of goods; and
- holding of special events and constraints on adjacent construction.

4.2 Construction Activities

The construction activities for the rapid transit Concept Design are similar to those that would be undertaken in upgrading a major road on the Gold Coast. The key construction activities are described below:

Preliminary Works

These include demolition of acquired properties, accommodation works on impacted properties, removal and relocation of street furniture.

Public Utilities Services Relocation

The linear nature of the Project and its location primarily within road corridors mean that the rapid transit system will intersect with a large number of public utility services. Additionally, as the Project's operational requirements include long operating hours, a high frequency service, and a high level of reliability of service, there is a need to ensure that the underlying utility services and the Project interface efficiently. Utility providers require access to their assets to undertake routine and unplanned maintenance and the rapid transit system requires the utility providers to not disrupt the operation of public transport services.

Utility services run both laterally (across the rapid transit system), and longitudinally (parallel to the direction of the rapid transit system). Where the utility services run laterally, the LRT track form may be designed to bridge over the service and as a minimum, the utility will be protected during the construction of the LRT infrastructure. Where the utility runs longitudinally, the service may need to be relocated outside the LRT running way to ensure that both the LRT system and the utility can operate as required.

Where relocations are required within areas subject to road widening, these will be targeted as early as possible in the construction program, to minimise reduced capacity of services and potential time delays.

The key utility service providers and the services within the corridor are:

- GCCC (water, stormwater and sewerage);
- Energex (power supply);
- Telstra (communications);
- Optus (communications);
- Uecomm (communications);
- Nextgen (optical fibre communications);
- PowerTel (optical fibre communications); and
- Australian Pipeline Trust (gas).

Further detail of the services to be protected or relocated is provided in Volume 2, Chapter 6 titled *Construction Issues*.

Construction

Where construction is taking place within an existing road corridor, the typical construction sequence is as follows:

- widening of the existing road reserve with reinstatement of a new footpath and travel lane on one side of corridor;
- construction of the rapid transit corridor which is undertaken in two parts. While one rapid transit lane is being constructed, the other lane is used as service road for construction vehicles;

- transfer of road vehicles onto the completed running way and reconstruction of travel lane and footpath on the other side of the road; and
- construction of stations, installation of Intelligent Transport System (ITS) system equipment and landscaping.

The two major bridges over Smith Street and Loders Creek and over the Nerang River are both approximately 400 metres in length. The construction of these bridges may be initiated in any early works packages.

Commissioning Activities

Commissioning activities include the following:

- commissioning of third party assets (roads, footpath and utilities). This will be an ongoing activity during the construction period;
- commissioning of vehicles. This will include test running and performance testing on a complete section of the rapid transit corridor running way designated as a test area; and
- commissioning of the rapid transit system. This includes testing interfaces with traffic signals and optimisation of traffic operations, testing the overhead power supply, switches (LRT), communications and vehicle tracking with the Control Centre and real time information.

Further information may be found in Volume 2, Chapter 6 *Construction Issues*.

5 Operations and Maintenance

The operations and maintenance phase of the Concept Design has been developed to meet the requirements of the Project Output Specification and the expected demand as forecast by traffic and transport modelling. The Concept Design operating period is 30 years. This is consistent with the financial analysis that is being undertaken and is supported by the transport modelling which has been forecast for 30 years. Key features of the operations and maintenance phase are outlined below.

5.1 Proposed Hours of Rapid Transit System Operation

Based on the existing demand pattern for bus lines operating along the proposed route, it is proposed that the rapid transit system will operate 24 hours a day with maximum headways (i.e. time between vehicles) at the start of operations as follows:

Time	Core (minutes)	Non-core (minutes)
Peak (0700-1800)	7.5	15
Off-peak (0600-0700, 1800-2300)	15	30
Night (2300-0600)	30	30

The use of different headways is designed to meet patronage demand during different times of the day. As the demand increases over time, headways will be reduced to increase capacity and additional vehicles will be purchased. Further information may be found in Volume 2, Chapter 7 *Operations*.

5.2 Routine and Major Periodic Maintenance

The assets of the rapid transit system will be maintained regularly to a high standard to ensure the safe and reliable operation of the system. In addition to routine maintenance activities, the key assets of the system that will require significant maintenance or renewal during the life of the Project include:

- pavement (BRT);
- track (LRT);
- overhead catenary (power supply for LRT);
- stations;
- vehicles; and
- control and information systems.